Why You Should Pay Attention!!

Changes to Achieve Better Performing Concrete Pavements

Purdue Road School
March 11, 2020
West Lafayette, IN

ACPA
INDIANA CHAPTER

Concrete

The most widely used, most versatile, most durable & most sustainable construction material

ACPA
INDIANA CHAPTER

Concrete Parking Lots

Urban Streets

County Roads

Interstates


GOMACO
GHP2800

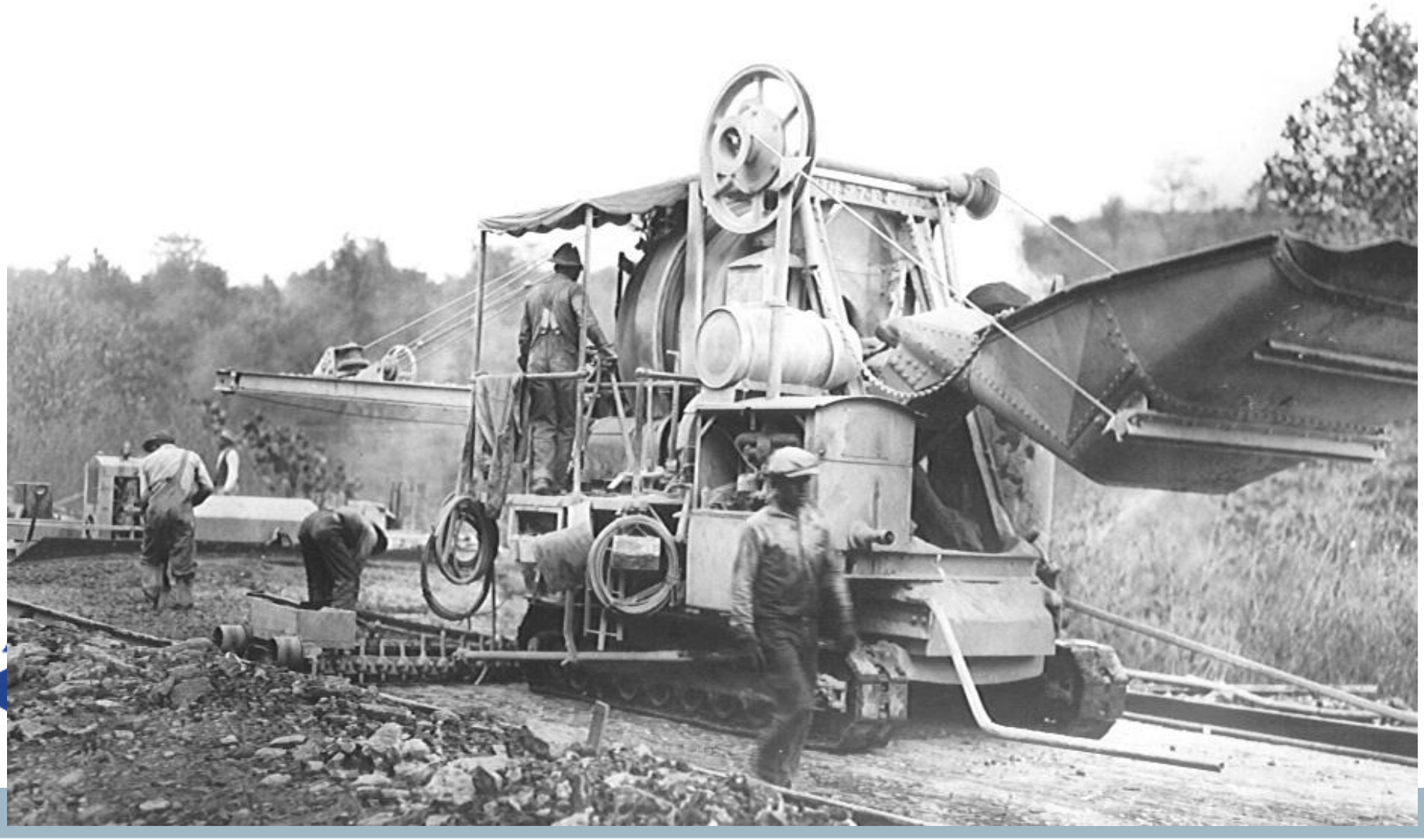
PCCP Overlays

ACPA
INDIANA CHAPTER

Changes have occurred in Materials & Construction

Demand to build it faster, under traffic
& last longer

ACPA
INDIANA CHAPTER



Central Mix Batch Plant

ACPA
INDIANA CHAPTER


COMACO
GHP 2800


Wirtgen


SP 25
Wirtgen

But in recent years, some problems arose impacting PCCP performance

ACPA
INDIANA CHAPTER

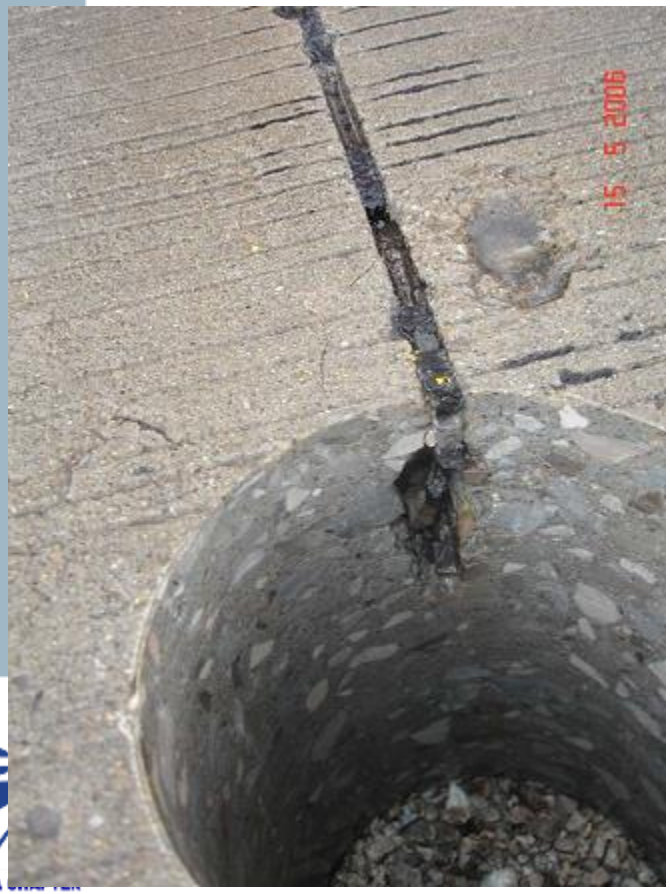
Joint Performance Issues

ACPA
INDIANA CHAPTER

New Challenge

ACPA
INDIANA CHAPTER

WHAT IS GOING ON?



Nature of Problem

- 5-15 year old PCCP shows deterioration at joints

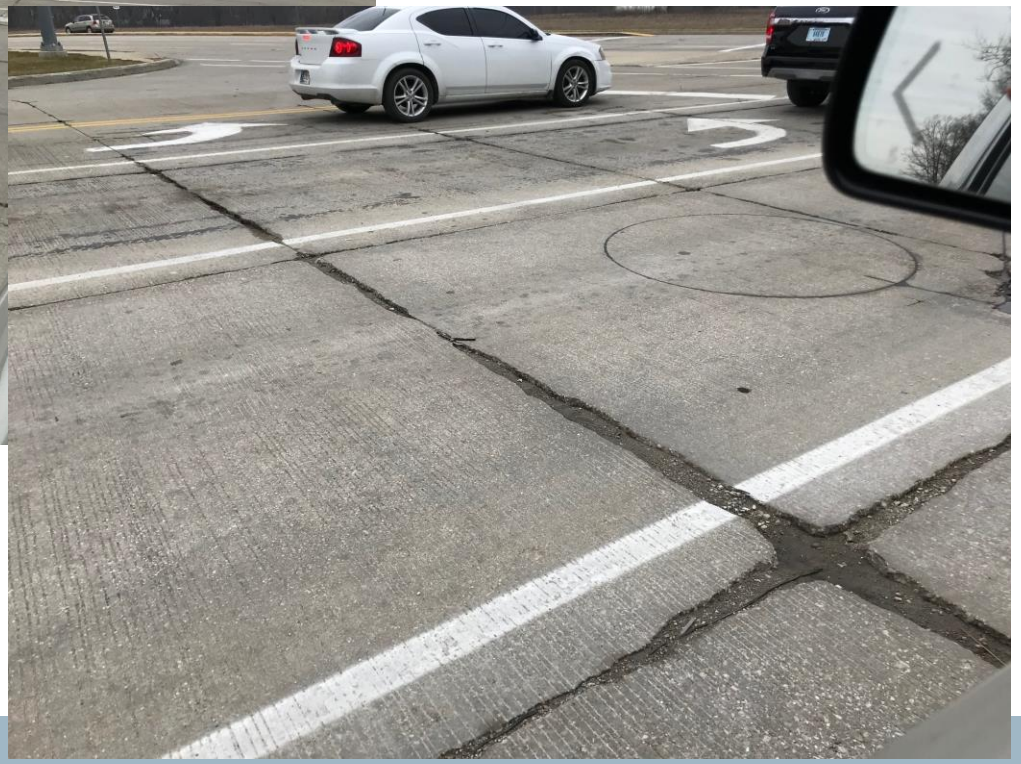
ACPA
INDIANA CHAPTER

Initially observed in streets & roads – but distress carries over to curbs, sidewalks & drives

ACPA
INDIANA CHAPTER

ACPA
INDIANA CHAPTER

COMPLEX PROBLEM



ACPA
INDIANA CHAPTER

Causes??
Observations??

Numerous JTRP research projects funded & conducted by Purdue Materials Faculty & Students, INDOT & Industry members

ACPA
INDIANA CHAPTER

Our research began to look at this differently

Zones of High Fluid Saturation

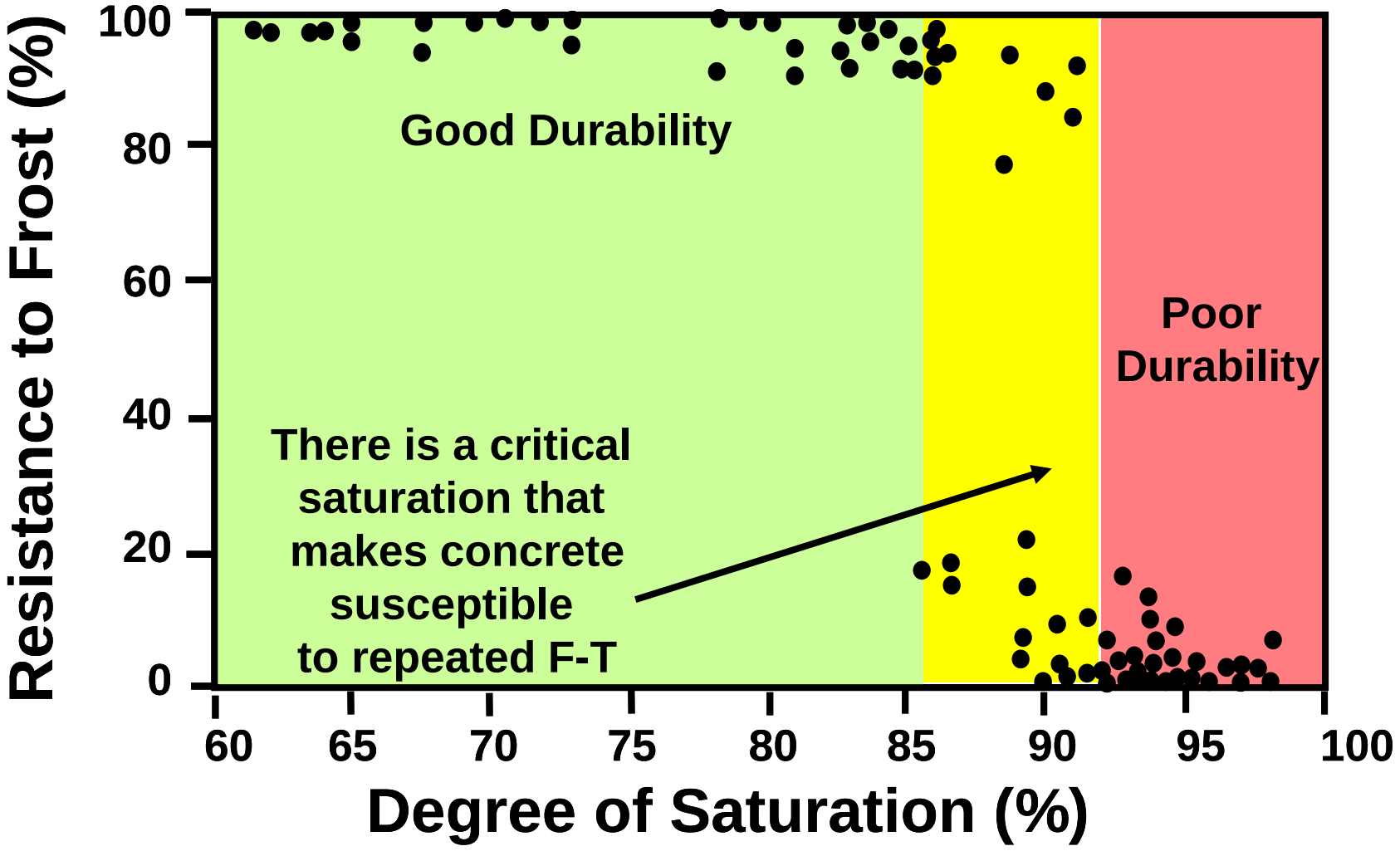
- Geometry
- Fluid Sits
- Fluid is not Water

Zones of Chemical Attack

- ‘New’ Salts
- ‘New’ Reactions
- ‘New’ Problem

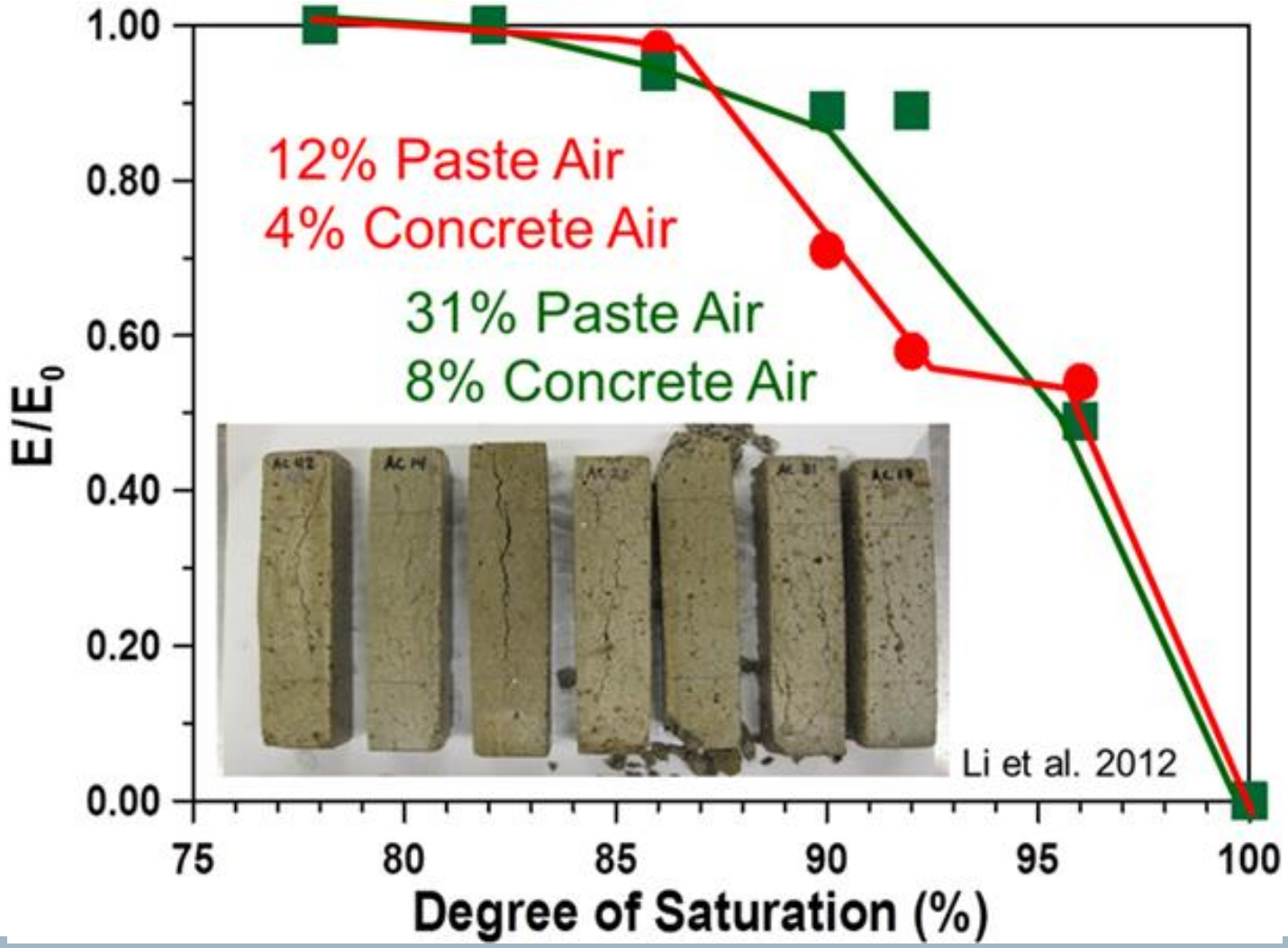
ACPA
INDIANA CHAPTER

High Saturation Leads to Damage

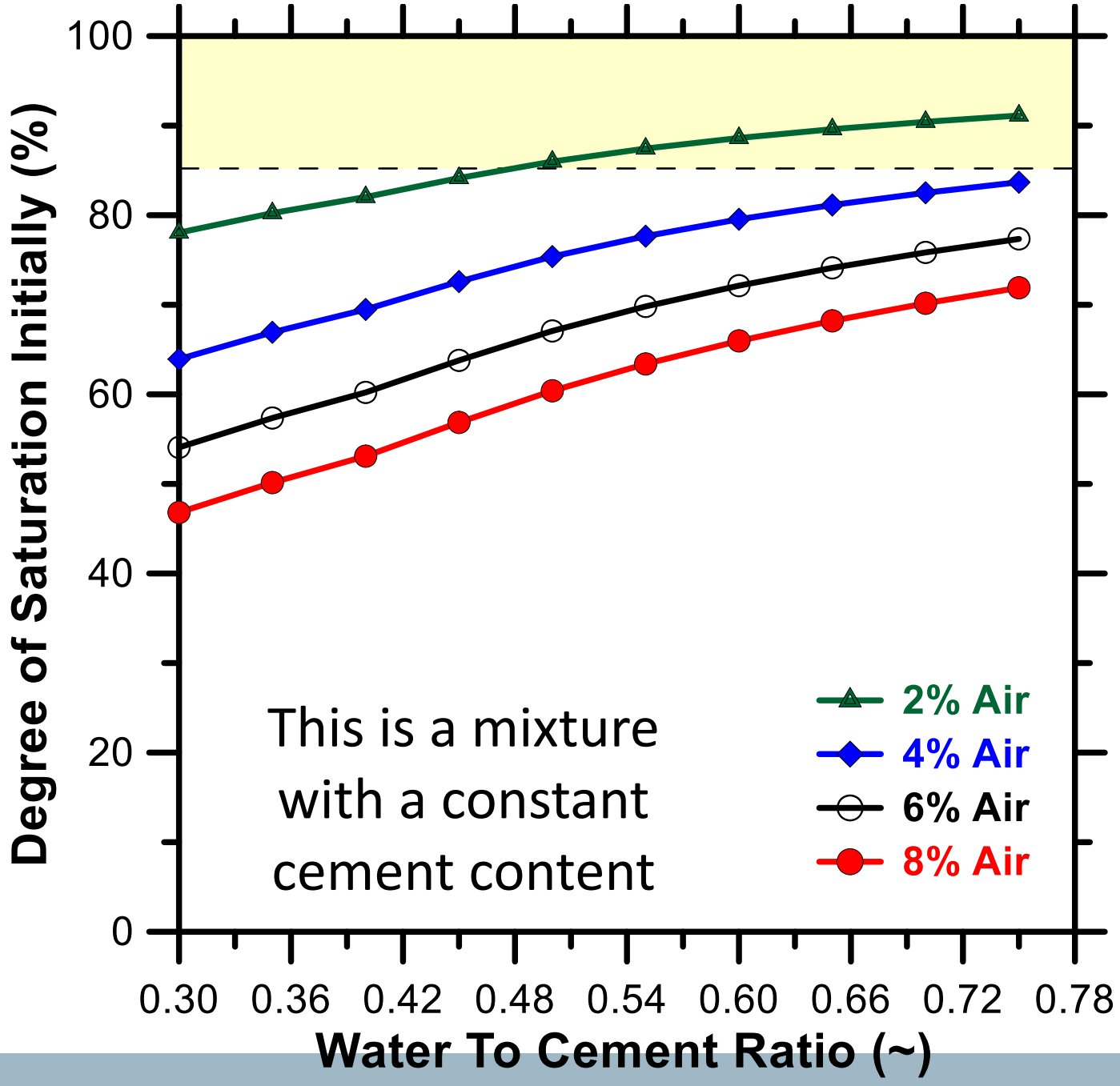


After CEB 1957

High Saturation Leads to Damage



ACPA
INDIANA CHAPTER



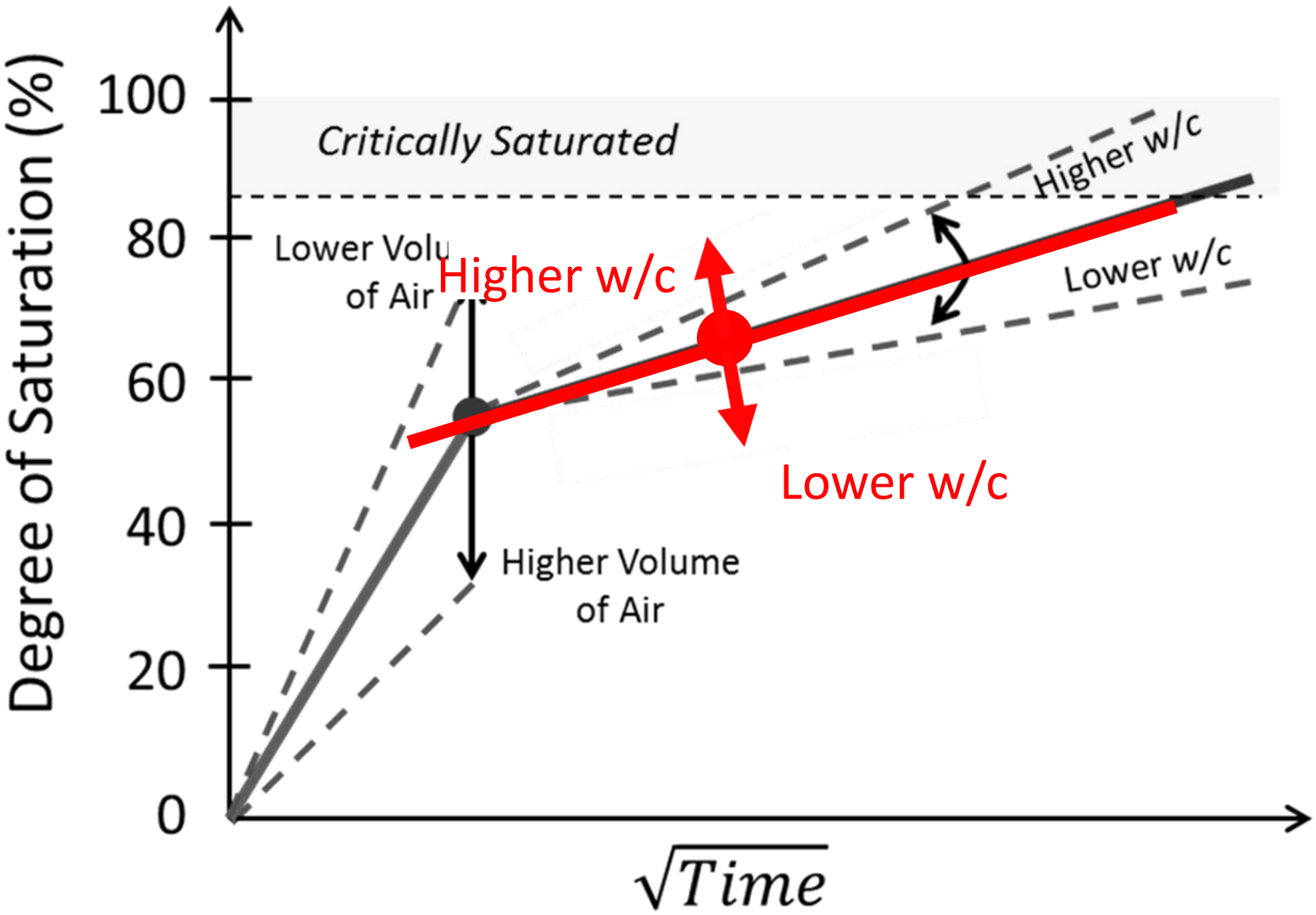
ACPA
INDIANA CHAPTER

Early Findings/Focus

- Poor air-entrainment systems
- Infilled air voids
- Paste quality
- Saturation
- Other- unidentified causes

ACPA
INDIANA CHAPTER

Sorption Model

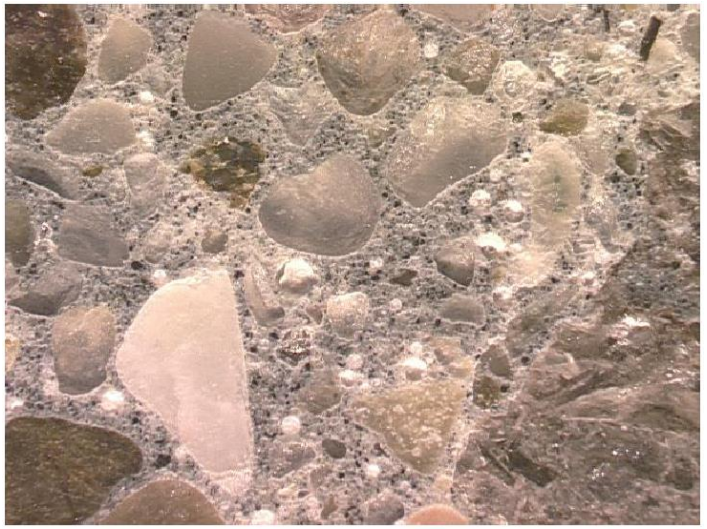


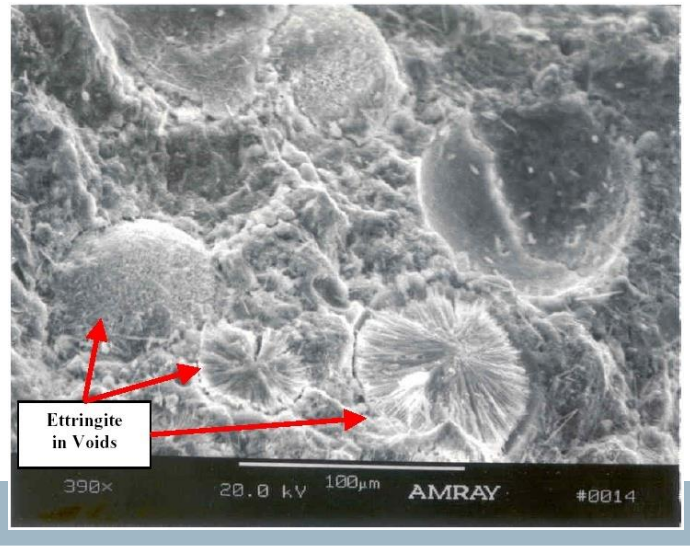
ACPA
INDIANA CHAPTER

Todak et al. 2015

Results from FHWA

- Air voids filled with hydration products (secondary products)
- Secondary product (ettringite) in air entrained small bubbles





ACPA
INDIANA CHAPTER

Early Findings

- Poor air-entrainment systems
- Infilled air voids
- Paste quality
- Saturation
- Other- unidentified causes

Change in de-icing practices remained the "big elephant" in the room

ACPA
INDIANA CHAPTER

Change in De-icing Practices

Cocktails of chemicals designed to de-ice at lower temperatures

“Super Salts”

ACPA
INDIANA CHAPTER

What Has Changed?

ACPA
INDIANA CHAPTER

Treated Salts

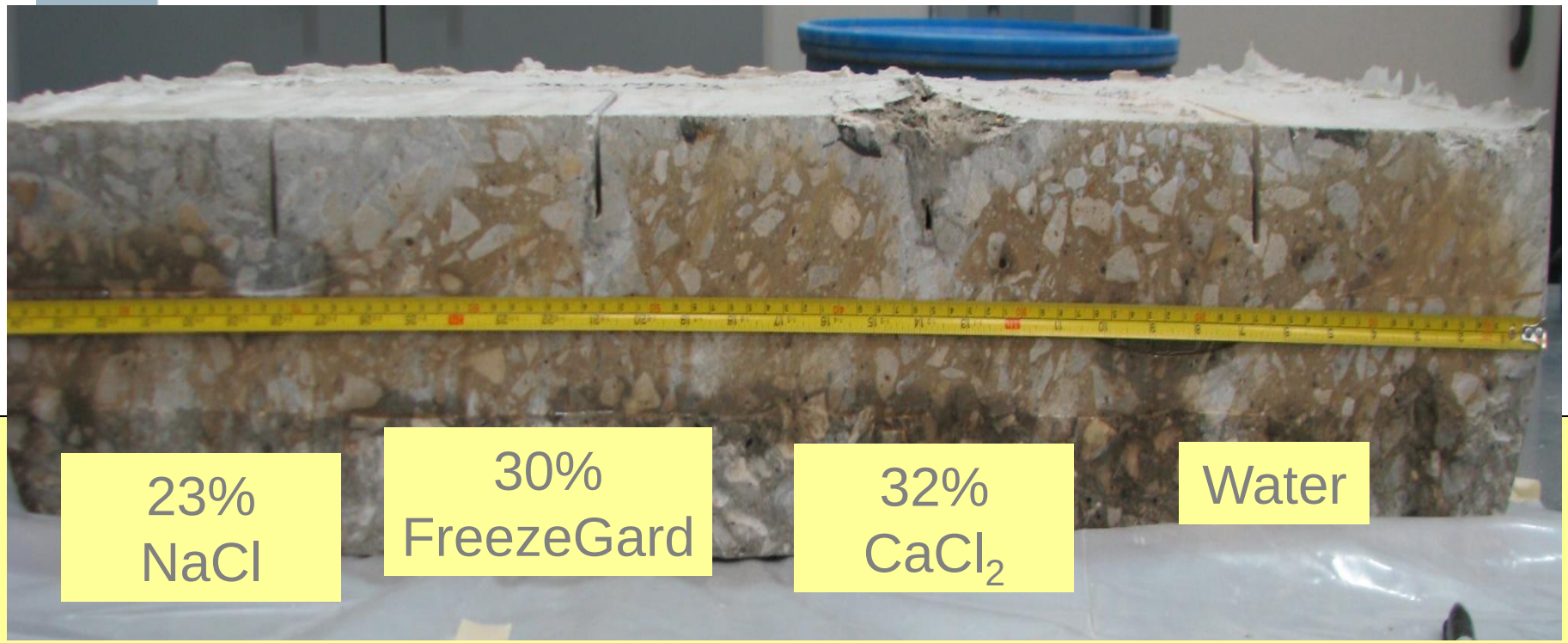
ACPA
INDIANA CHAPTER

What Are Super Salts

- Calcium and/or magnesium chloride treated sodium chloride
- Can be placed as a solid
- Can be place as a portion of pretreating

ACPA
INDIANA CHAPTER

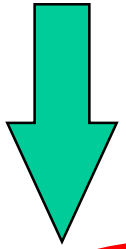
Deicers – Do Impact Performance



It is a problem of critical saturation & chemical attack

ACPA
INDIANA CHAPTER

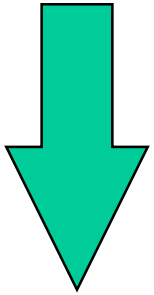
CEMENT + WATER



$CS(glue) + Ca(OH)_2 + H_2O$

ACPA
INDIANA CHAPTER

$$Ca(OH)_2 + H_2O + CaCl_2$$



Calcium Oxychloride

BAD Actor!!

ACPA
INDIANA CHAPTER

So how do fix/prevent the deterioration

ACPA
INDIANA CHAPTER

Summary of Recommendations

Volume of Air

Volume of Paste

SCM Use

Concrete Sealer

W/C

F. Factor

Backer Rod

Reduce Tie

Bar Size/Spacing

Opening Strength

Strength Acceptance

Joint Sealant

Detection

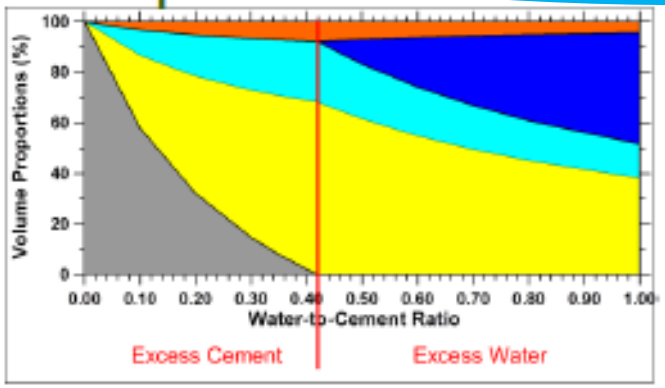
Summary

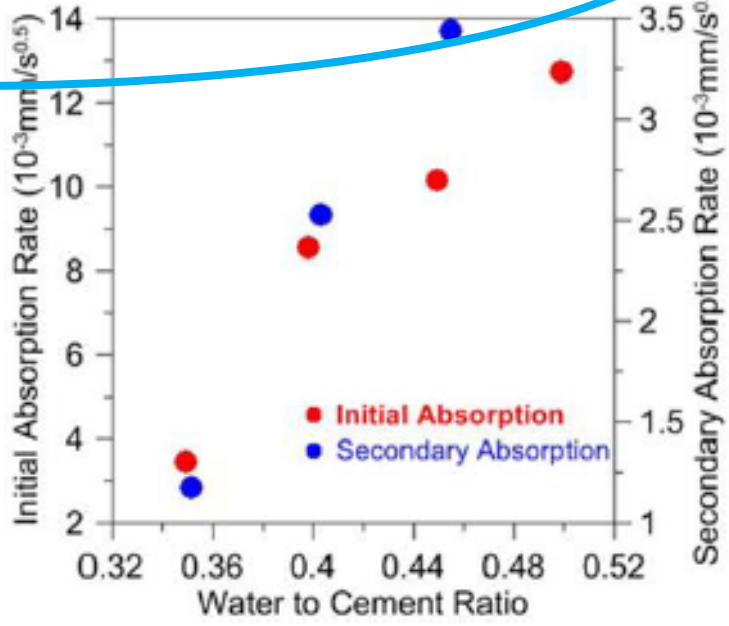
1. Volume of Air (lower bound move 5.0 to 5.5)
2. Volume of Cement (cementitious content)
3. Water to Cement (0.45 to 0.44)
4. Formation Factor (implement a pay factor)
5. Supplementary Cementitious Materials Use
6. Use Concrete Sealers (penetrating sealer)
7. Tie Bar and Spacing (already Implemented)
8. Remove Backer Rod
9. Remove Joint Sealant
10. Reduce Opening Strength
11. Use Maturity to Determine Acceptance Str at 7d
12. Detection of the Problem (Use of GPR CID)

3. Water to Cement Ratio

- Volume of Air
- Volume of Paste
- SCM Use
- Concrete Sealer
- W/C
- F. Factor
- Backer Rod
- Reduce Tie
- Bar Size/Spacing
- Opening Strength
- Strength Acceptance
- Joint Sealant
- Detection
- Summary

- Change the current upper bound on w/c from 0.45 to a max of 0.44 or lower
- Impact - Low Risk



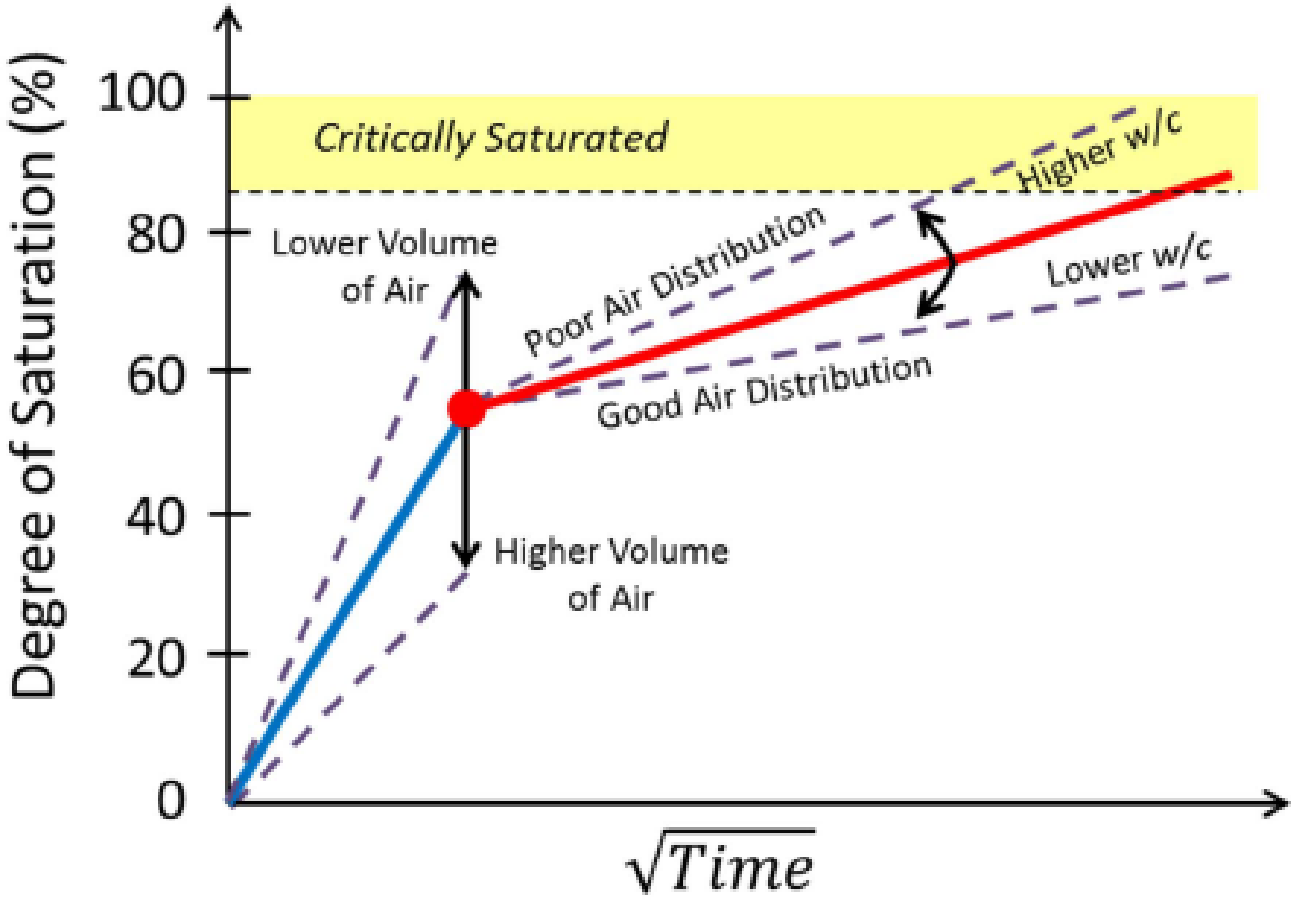


NPFS: (co-PI Weiss) Improving Specifications to Resist Frost Damage in Modern Concrete Mixtures

SPR 2474 (PI Weiss and Olek) Interaction Between Micro-Cracking, Cracking, and Reduced Durability of Concrete: Developing Methods for Considering Cumulative Damage in Life-Cycle Modeling

Concept: Examining the Volume of Air and the Water to Cement Ratio

- Volume of Air
- SCM Use
- Concrete Sealer
- W/C
- F. Factor
- Backer Rod
- Reduce Tie
- Bar Size/Spacing
- Opening Strength
- Strength Acceptance
- Joint Sealant
- Detection



NPFS: (co-PI Weiss) Improving Specifications to Resist Frost Damage in Modern Concrete Mixtures

Spec changes

Concrete Mix Criteria

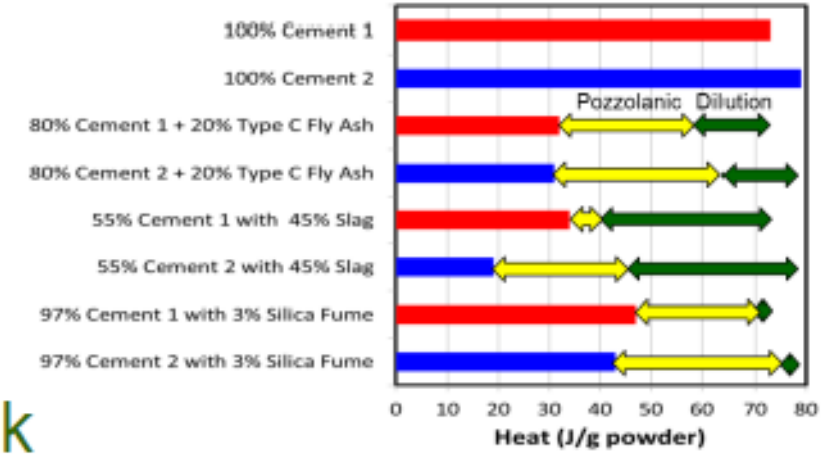
The CMD shall contain at least one, but no more than two SCM's, and produce workable concrete mixtures having the following properties:
Minimum total cementitious content defined by CMDP..... 500 lbs/cu yd
Allowable amount of single SCM defined by CMDP,
% of total cementitious, by weight..... 20.0-40.0% A
Allowable amount of two SCM's defined by CMDP,
% of total cementitious, by weight..... 25.0 – 40.0% B
Minimum portland cement content defined by CMDP..... 350 lbs/cu yd
Allowable amount of silica fume SCM defined
by CMDP, % of total cementitous content..... 3.0 – 7.0%
Maximum allowable water/cementitious ratio of concrete
mixture with fly ash SCM..... 0.440
Maximum allowable water cementitious ratio of concrete
mixture with ggbfs SCM..... 0.450
Target air content defined by CMDP..... 7.0%
Minimum flexural strength, third point loading..... 570 psi at 7 days

ACPA
INDIANA CHAPTER

5. Mitigation of the Problem - SCM

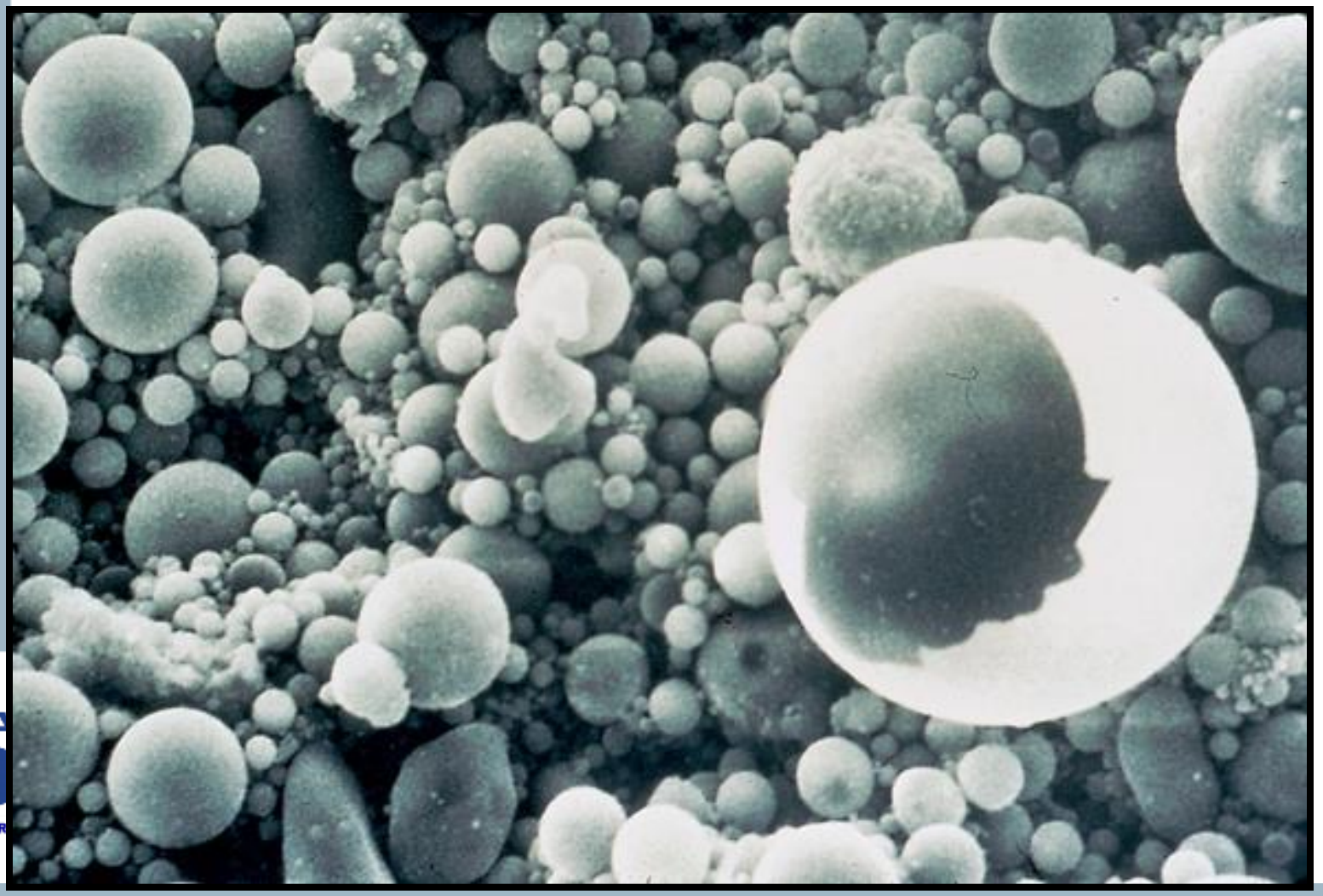
Volume of Air
Volume of Paste
SCM Use
Concrete Sealer
W/C
F. Factor
Backer Rod
Reduce Tie
Bar Size/Spacing
Opening Strength
Strength Acceptance
Joint Sealant
Detection
Summary

- Use SCM to mitigate Ca-Oxy
- Initial – Recommend Minimum SCM
- Long Term – LTDSC Test Qualification
- Remove current calendar limit on SCM use for slip form paving
- Examine SCM restriction limits
- Allow Ternary
- Impact – Low Risk (scaling). reduce risk in bidding potential lower cost



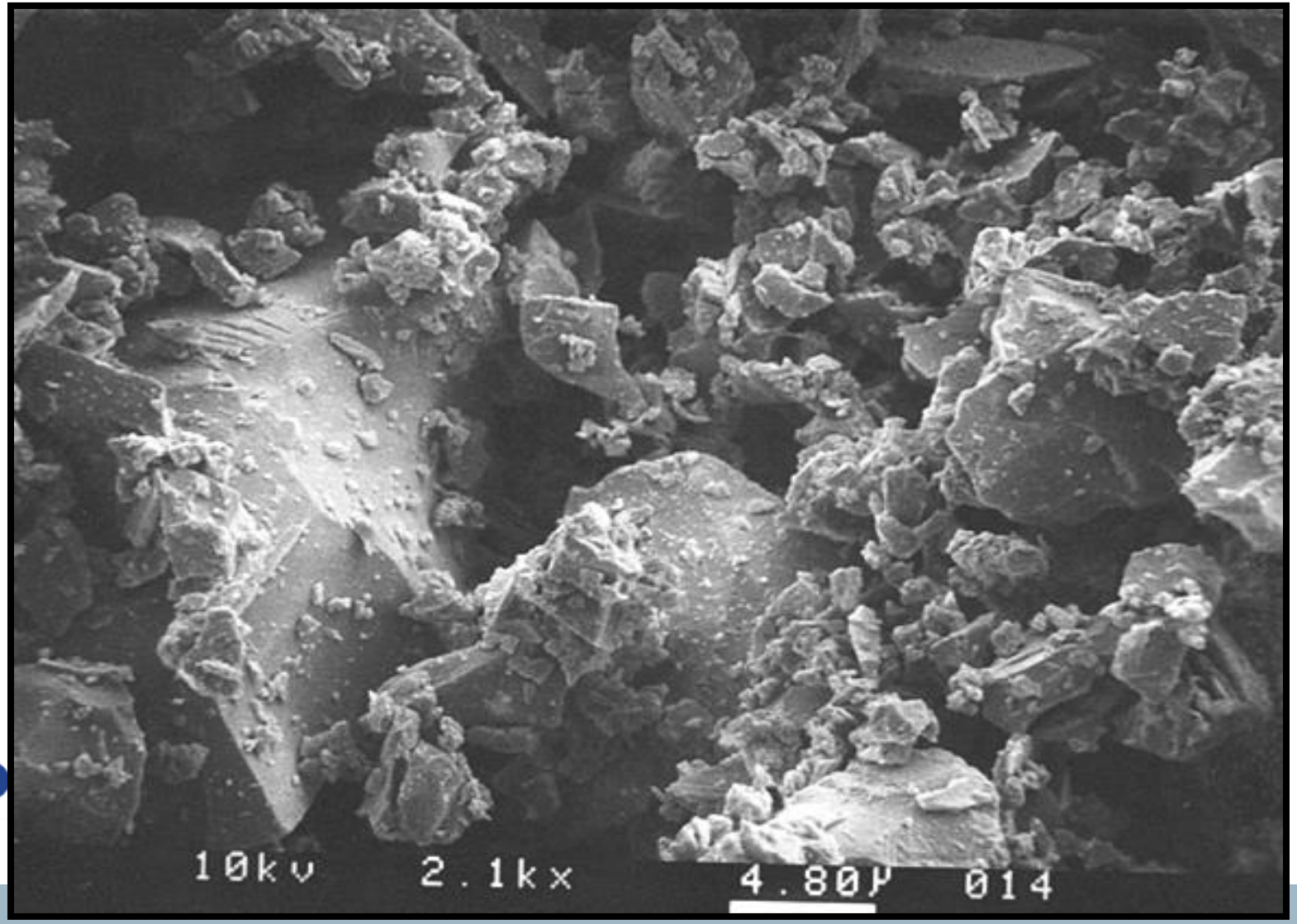
SPR 2475: (PI Olek and Weiss) Technical Issues Related to the Use of Fly Ash and Slag During the Late Fall (Low Temperature) Construction Systems
SPR 3864: (PI Weiss) Performance of Deicing Salts and Deicing Salt Cocktails

SEM of Fly Ash Particles



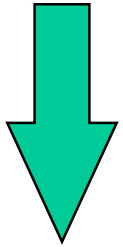
ACPA
INDIANA CHAPTER

SEM of Slag Particles



ACPA
INDIANA CHAPTER

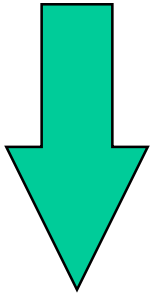
CEMENT + WATER



$CS(glue) + Ca(OH)_2 + H_2O$

ACPA
INDIANA CHAPTER

$Ca(OH)_2 + H_2O + Pozzolan$

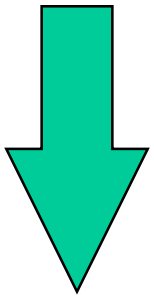


$CS(glue) + H_2O$

ACPA
INDIANA CHAPTER

SCM

$Ca(OH)_2 + H_2O + CaCl_2$



More Paste

Calcium Oxychloride

BAD Actor!!

ACPA
INDIANA CHAPTER

Spec changes

Concrete Mix Criteria

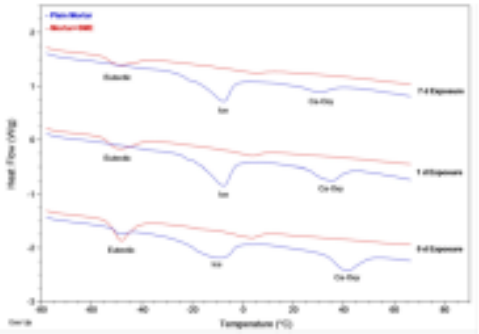
The CMD shall contain at least one, but no more than two SCM's, and produce workable concrete mixtures having the following properties:
Minimum total cementitious content defined by CMDP..... 500 lbs/cu yd
Allowable amount of single SCM defined by CMDP,
% of total cementitious, by weight..... 20.0-40.0% A
Allowable amount of two SCM's defined by CMDP,
% of total cementitious, by weight..... 25.0 – 40.0% B
Minimum portland cement content defined by CMDP..... 350 lbs/cu yd
Allowable amount of silica fume SCM defined
by CMDP, % of total cementitous content..... 3.0 – 7.0%
Maximum allowable water/cementitious ratio of concrete
mixture with fly ash SCM..... 0.440
Maximum allowable water cementitious ratio of concrete
mixture with ggbfs SCM..... 0.450
Target air content defined by CMDP..... 7.0%
Minimum flexural strength, third point loading..... 570 psi at 7 days

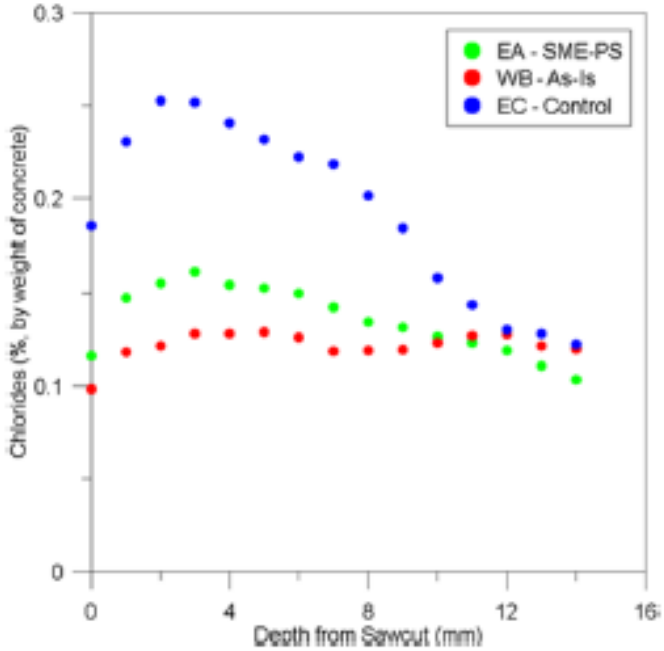
ACPA
INDIANA CHAPTER

6. Mitigation of the Problem - Sealer

- Volume of Air
- Volume of Paste
- SCM Use
- Concrete Sealer
- W/C
- F. Factor
- Backer Rod
- Reduce Tie
- Bar Size/Spacing
- Opening Strength
- Strength Acceptance
- Joint Sealant
- Detection
- Summary

- Use concrete sealant to reduce Ca-Oxy
- Use concrete sealer with open joints on new or existing joints
- Impact – Open Joints, Potential LCA saving





SPR 3200: (PI Weiss) Durability of Saw-Cut Joints in Plain Cement Concrete Pavements

SPR 3523: (PI Weiss) Evaluation of Sealers and Waterproofers for Extending the Life Cycle of Concrete

Freeze-Thaw Durability

Plain SME-PS Dose 1 SME-PS Dose 2 SBS

Summary of Recommendations

1. Volume of Air (lower bound move 5.0 to 5.5)
2. Volume of Cement (cementitious content)
3. Water to Cement (0.45 to 0.44)
4. Formation Factor (implement a pay factor)
5. Supplementary Cementitious Materials Use
6. Use Concrete Sealers (penetrating sealer)
7. Tie Bar and Spacing (already Implemented)
8. Remove Backer Rod
9. Remove Joint Sealant
10. Reduce Opening Strength
11. Use Maturity to Determine Acceptance Str at 7d
12. Detection of the Problem (Use of GPR CID)

Conclusion

- Had a problem
- Solutions found
- Suggest utilize new recommendations & Specs to achieve even better PCCP performance

ACPA
INDIANA CHAPTER

Questions?

Information:
Mike Byers
Indiana Chapter ACPA
mbyers@pavement.com
www.indianaconcretepavement.com

ACPA
INDIANA CHAPTER